(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
14.01.1998 Bulletin 1998/03

(51) Int Cl.6: **G01F 1/66, G01F 1/00,**
G01F 1/712, G01F 23/28,
G01P 3/68, G01P 5/18,
G01P 21/02

(21) Application number: 92630090.6

(22) Date of filing: 24.09.1992

(54) **Method for measuring liquid flow**

Verfahren zur Durchflussmessung.

Procédé pour la mesure d'un écoulement liquide

(84) Designated Contracting States:
DE FR GB IT NL

(30) Priority: **04.10.1991 US 771903**

(43) Date of publication of application:
07.04.1993 Bulletin 1993/14

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Description

The present invention relates to a method for measuring liquid flow. The invention is particularly useful for measuring the flow of milk, and is therefore described below particularly with respect to this application, but it will be appreciated that the invention could advantageously be used for measuring the flow of other liquids, particularly mixtures.

Existing methods of measuring milk flow are generally based on mechanical type measuring devices. One way of electrically measuring milk flow is to subject the milk to electromagnetic radiation and to measure the attenuation of the electromagnetic radiation by the milk. However, the composition of the milk varies substantially from cow to cow, and even from the same cow during the same milking process. Such variations in composition affect the attenuation of the electromagnetic radiation by the milk and thereby affect the measurements in a significant manner.

An object of the present invention is to provide a method for measuring liquid flow in which variations in the composition of the liquid do no significantly affect the measurements.

According to the present invention, there is provided a method of measuring liquid flow, comprising the steps: (a) directing the liquid to flow through a flow channel of known dimensions while exposing the liquid to electromagnetic radiation; (b) measuring the momentary attenuation of the electromagnetic radiation by the liquid flowing through the flow channel; (c) measuring the relative transparency to electromagnetic radiation of the liquid flowing through the flow channel for calibration purposes; (d) determining from the foregoing measurements the momentary volume of the liquid flowing through the flow channel; (e) determining the momentary velocity of the liquid flowing through the flow channel; and (f) determining from steps (d) and (e) the momentary flow rate of the liquid flowing through the flow channel.

In a preferred embodiment of the invention described below, the electromagnetic radiation is infrared light. A second embodiment is described wherein the electromagnetic radiation is in the radio frequency band.

As will be described more particularly below, the method of the present invention is particularly useful for measuring the flow rate of milk since the results are not significantly affected by changes in composition of the milk from cow to cow, or even from the same cow. Moreover, the results produced by the method also provide information useful in indicating the actual composition of the milk whose flow rate is being measured. Thus, the latter feature makes it possible to estimate the milk's different components, such as relative percentages of fat and protein, since these relative percentages influence the absorption of the light from the light source.

Fig. 1 illustrates one form of measuring apparatus constructed in accordance with the present invention utilizing infrared radiation;
Fig. 2 is a block diagram of a system including the apparatus of Fig. 1;
Fig. 3 are waveforms helpful in understanding the method and apparatus of the present invention;
and Fig. 4 illustrates a second embodiment of the invention utilizing RF (radio frequency) radiation.

The apparatus illustrated in Fig. 1 includes a measuring head, generally designated 2, having an inlet 4 connected to a conduit 6 leading from a source of the liquid to be measured (e.g., milk from a cow milking machine), and an outlet 8 connected to an outlet conduit 10 (e.g., leading to a container for receiving the milk). As the milk flows through measuring head 2, its flow rate is continuously measured in a real time manner despite variations in the composition of the milk.

The outlet conduit 10 would normally be connected to a vacuum source. Thus, when the flow of milk through the measuring head 2 is not continuous, air "bubbles", or milk "pulses", would be produced in the flow of the milk through the measuring head.

Measuring head 2 includes, adjacent to its inlet end 4, a plurality of partitions 12 which divide the inflowing milk into a plurality of parallel flow channels 14. Each of the flow channels 14 is of known dimensions, in that both its width and height are known. However, the flow channels 14 are designed, as compared to the range of flow rate of the milk to be measured, so that the channels are not completely filled by the milk at the time the measurements are made. Accordingly, the volume of each channel will vary in accordance with the flow rate of the milk through that channel.

Measuring head 2 further includes two lines of electromagnetic radiation sources, such as infrared light sources, each aligned with, and on one side of, each of the flow channels 14. In the example illustrated in Fig. 1, there are seven flow channels 14, and therefore there is a first line of seven light sources 20, and a second line of seven light sources 22 spaced from line 20 towards the outlet end 8 of the housing. The distance between the two lines of light sources 20, 22 is precisely known. This enables a determination of the velocity of the milk flow to be made, as will be described more particularly below. Each of the light sources 20, 22 is aligned with a light detector 24, 26, at the opposite side of the respective channel 14, so that each detector 24, 26 measures the attenuation of the light produced by the milk passing through the respective channel 14.

Measuring head 2 includes a further channel 30, serving as a calibrating channel, through which the milk is directed after it leaves the seven flow channels 14. Calibrating channel 30 is also of known dimensions, but in this case the channel is completely filled with milk when measurements are taken, as distinguished from the flow channels 14 which may not be completely filled with milk during the normal working ranges of the illus-

trated apparatus. Calibrating channel 30 is used for measuring the relative transparency of the milk. For this purpose, the calibration channel 30 is also equipped with a light source 32 and a detector 34 on the opposite sides of the channel.

The milk, after passing through calibration channel 30, passes through another calibration station 36 between the calibration channel 30 and the housing outlet 8. Calibration station 36 is also equipped with a light source 38 and detector (40, Fig. 2). The light source 38 and its corresponding detector 40 are subjected to the same temperature as the milk flowing through channels 14 and 30, but they are physically insulated from the milk so that the detected radiation is influenced, not by the attenuation of the radiation caused by the milk, but only by the temperature variations of the milk.

The overall system including the measuring head 2 illustrated in Fig. 1, is more particularly illustrated in the block diagram of Fig. 2. It will thus be seen that the radiation from the line of light sources 20 passes through the milk flowing through the flow channels 14, so that the radiation detected by each of the detectors 24 at the opposite side of reach channel provides an indication of the momentary attenuation produced by the milk flowing through the respective channel. A similar measurement is provided by the second line of light sources 22 and their respective detectors 26. Since the distance between the two lines of light sources is known, the velocity of the milk flowing through the flow channels 14 can be determined.

This is more particularly illustrated in Fig. 3, wherein it will be seen that the broken-line waveform, corresponding to the outputs of detectors 26 cooperable with the line of light sources 22 lags the full-line waveform, correspond to the outputs of detectors 24 cooperable with the line of light sources 20 because of the distance between the two lines of light sources and detectors. Since this distance is known, and since this lag can be measured, the velocity of the milk flowing through the flow channels 14 can be determined.

The outputs of the two groups of detectors 24, 26 are fed, via an amplifier 50 and an analog-to-digital converter 52, to a microprocessor 54 which makes this determination.

Detector 34, aligned with light source 32 in the calibration channel 30, also produces an output which is applied, via amplifier 50 and converter 52, to the microprocessor 54. As described earlier, since the calibration channel 30 is always full of milk, the output of its detector 34 will not provide an indication of the relative volume of the channel occupied by the milk, but rather of the relative transparency of the milk flowing through that channel. Thus, the higher the percentage of fat in the milk, the lower will be the relative transparency of the milk to the radiation, and therefore the higher will be the attenuation resulting from the passage of the radiation through the milk.

Microprocessor 54 receives the outputs from the two groups of detectors 24, 26, and also from the calibration detector 34. Microprocessor 54 includes a non-volatile memory 56 that contains a table for converting the measurements of detectors 24, 26, and also of a calibration detector 34, to the relative volume of the flow channels 14 occupied by the milk passing through these channels. Since microprocessor 54 also determines (from the two lines of detectors 24, 26) the velocity of the milk passing through these channels, the microprocessor is able to determine the flow rate of the milk at any instant irrespective of its transparency.

The amount of light absorbed by the milk flowing through the flow channels 14 is dependent, not only on the relative volume of the milk actually occupying the respective channel and the composition (transparency) of the milk in the channel, but also on the frequency of the radiation of its respective source (20, 22). Thus, the light sources 20 and their detectors 24 in some or all of the channels could be selected to operate at different frequencies, so that the information received by their respective detectors 24 will provide an indication of the relative composition of the milk then being measured, e.g., the relative percentage of fat and protein.

Detector 40 feeds it output, which varies with the temperature, to a stabilization unit 58. This unit controls the energy supplied to all the light sources 20, 22, 32 and 38, in order to compensate the measurements for changes in temperature and ageing effects.

In order to obtain a precision of ± one percent, which is generally more than adequate for the consumer, it is possible to use low sample rates, in the region of 3-30 Khz, and a data word width of eight bits. These sample rates and data widths enable the use of standard low cost analog-to-digital components and microprocessors. The radiation sources and detectors may change by ageing. Ageing can be measured by examining the values obtained in the receivers while the channels are empty, and may also be compensated for by updating the table stored in the memory 56.

Fig. 4 illustrates one flow channel 60, corresponding to one of the seven flow channels 14 in Fig. 1, in a system wherein the electromagnetic radiation is RF (radio frequency) radiation rather than infrared radiation. The milk is circulated through flow channel 60 via its inlet 62 and its outlet 64. Channel 60 is of known dimensions, which are predetermined such that the channel is not completely filled by the milk at the time the measurements are made, and therefore the volume of each channel will vary in accordance with the flow rate of the milk through that channel, as described above with respect to channels 14 in Fig. 1.

Channel 60 includes a source of RF radiation in the form of a transmitter coil 66 driven by an RF oscillator 68. Channel 60 further includes two receiver coils 70, 72 spaced equal distances from, and on opposite sides of, the transmitter coil 66. The milk flowing through channel 60 thus absorbs the radiation corresponding to the volume of the milk within the channel, so that the outputs

of the two receiver coils 70, 72 will provide an indication of the amount of energy absorbed by the milk flowing through the channel, and thereby an indication of the relative volume of the channel occupied by the milk. The outputs of the two receiver coils 70, 72 are fed to detector circuits 74, 76, are converted to digital form in A/D converter 78, and are then inputted into microprocessor 80, corresponding to microprocessor 54 in Fig. 2.

It will also be appreciated that such a system could also include a calibration channel corresponding to calibration channel 30 in Fig. 2, and a calibration station corresponding to calibration 36 in Fig. 2, provided with a similar RF radiation transmitter and receiver as illustrated in Fig. 4, and that the velocity and calibration may be done in a similar manner as described above with respect to the infrared radiation system of Figs. 1-3.

Claims

1. A method of measuring liquid flow, comprising the steps:

    (a) directing the liquid to flow through a flow channel of known dimensions while exposing the liquid to electromagnetic radiation;
    (b) measuring the momentary attenuation of the elecromagnetic radiation by the liquid flowing through said flow channel;
    (c) measuring the relative transparency to electromagnetic radiation of the liquid flowing through said flow channel for calibration purposes;
    (d) determining from said measurements the momentary volume of said liquid flowing through said flow channel;
    (e) determining the momentary velocity of the liquid flowing through said flow channel; and
    (f) determining from said steps (d) and (e) the momentary flow rate of the liquid flowing through said flow channel.

2. The method according to Claim 1, wherein said transparency is measured by subjecting a known volume of the liquid to said electromagnetic radiation and measuring the attentuation thereof.

3. The method according to Claim 2, wherein said transparency of the liquid is measured by measuring the attenuation by the liquid of said electromagnetic radiation while the liquid flows through and fills a conduit of known dimensions.

4. The method according to Claim 3, wherein said conduit is a calibrating channel separate from said flow channel.

5. The method according to any one of Claims 1-4, wherein the momentary velocity of the liquid flowing through said flow channel is determined in step (e) by measuring the momentary attenuation of the electromagnetic radiation at two points along said flow channel spaced a known distance from each other.

6. The method according to any one of Claims 1-5, further including:

    (g) measuring changes in attenuation of the electromagnetic radiation across a path which is in series with said flow channel so as to be subjected to the same temperature of the liquid in said flow channel but which path does not contain the liquid from the flow channel, and controlling in response thereto said electromagnetic radiation to which the liquid in said flow channel is exposed to compensate for temperature changes and ageing effects.

7. The method according to any one of Claims 1-6, wherein:

    in step (a), said liquid is directed to flow through a plurality of channels in parallel to each other;
    in step (b), the momentary attenuation of the electromagnetic radiation is measured in each of said plurality of flow channels;
    and in step (d), the momentary volume of the liquid flowing through all said flow channels is measured to determine the momentary volume of the liquid flowing through all said flow channels.

8. The method according to Claim 7, wherein in step (b), the momentary attenuation of the electromagnetic radiation measured in at least some of said flow channels is of different frequencies, to thereby provide information useful in indicating the composition of the liquid flowing through said flow channels.

9. The method according to any one of Claims 1-8, wherein said electromagnetic radiation is infrared radiation.

10. The method according to any one of Claims 1-8, wherein said electromagnetic radiation is radio frequency radiation.

Patentansprüche

1. Verfahren zur Flüssigkeitsdurchflußmessung, beinhaltend die Schritte:

    (a) Hindurchleiten der Flüssigkeit durch einen

Durchflußkanal mit bekannten Abmessungen, während die Flüssigkeit mit elektromagnetischer Strahlung beaufschlagt wird;

(b) Messen der Augenblicksdämpfung der elektromagnetischen Strahlung durch die Flüssigkeit, die durch den Durchflußkanal fließt;

(c) Messen der relativen Transparenz der durch den Durchflußkanal fließenden Flüssigkeit für die elektromagnetische Strahlung zu Eichzwecken;

(d) Bestimmen des Augenblicksvolumens der durch den Durchflußkanal fließenden Flüssigkeit aus den Messungen;

(e) Bestimmen der Augenblicksgeschwindigkeit der durch den Durchflußkanal fließenden Flüssigkeit; und

(f) Bestimmen des Augenblicksdurchsatzes der durch den Durchflußkanal fließenden Flüssigkeit aus den Schritten (d) und (e).

2. Verfahren nach Anspruch 1, wobei die Transparenz gemessen wird, indem ein bekanntes Volumen der Flüssigkeit mit der elektromagnetischen Strahlung beaufschlagt und die Dämpfung derselben gemessen wird.

3. Verfahren nach Anspruch 2, wobei die Transparenz der Flüssigkeit durch Messen der Dämpfung der elektromagnetischen Strahlung durch die Flüssigkeit gemessen wird, während die Flüssigkeit eine Leitung mit bekannten Abmessungen durchfließt und füllt.

4. Verfahren nach Anspruch 3, wobei die Leitung ein von dem Durchflußkanal separater Eichkanal ist.

5. Verfahren nach einem der Ansprüche 1-4, wobei die Augenblicksgeschwindigkeit der durch den Durchflußkanal fließenden Flüssigkeit in dem Schritt (e) bestimmt wird durch Messen der Augenblicksdämpfung der elektromagnetischen Strahlung in zwei Punkten längs des Durchflußkanals, die um eine bekannte Strecke voneinander beabstandet sind.

6. Verfahren nach einem der Ansprüche 1-5, weiter beinhaltend:

(g) Messen von Änderungen in der Dämpfung der elektromagnetischen Strahlung auf einem Weg, der in Serie mit dem Durchflußkanal ist, so daß er derselben Temperatur der Flüssigkeit in dem Durchflußkanal ausgesetzt ist, wobei aber der Weg nicht die Flüssigkeit aus dem Durchflußkanal enthält, und entsprechendes Steuern der elektromagnetischen Strahlung, mit der die Flüssigkeit in dem Durchflußkanal beaufschlagt wird, um Temperaturänderungen

und Alterungseffekte zu kompensieren.

7. Verfahren nach einem der Ansprüche 1-6, wobei:

in dem Schritt (a) die Flüssigkeit durch mehrere Kanäle hindurchgeleitet wird, die zueinander parallel sind;

in dem Schritt (b) die Augenblicksdämpfung der elektromagnetischen Strahlung in jedem der Durchflußkanäle gemessen wird; und

in dem Schritt (d) das Augenblicksvolumen der durch alle Durchflußkanäle fließenden Flüssigkeit gemessen wird, um das Augenblicksvolumen der durch alle Durchflußkanäle fließenden Flüssigkeit zu bestimmen.

8. Verfahren nach Anspruch 7, wobei in dem Schritt (b) die Augenblicksdämpfung der elektromagnetischen Strahlung, die in wenigstens einigen der Durchflußkanäle gemessen wird, unterschiedliche Frequenzen hat, um dadurch Information zu liefern, die bei dem Anzeigen der Zusammensetzung der durch die Durchflußkanäle fließenden Flüssigkeit nützlich ist.

9. Verfahren nach einem der Ansprüche 1-8, wobei die elektromagnetische Strahlung Infrarotstrahlung ist.

10. Verfahren nach einem der Ansprüche 1-8, wobei die elektromagnetische Strahlung Hochfrequenzstrahlung ist.

Revendications

1. Procédé de mesure du débit d'un liquide comprenant les étapes consistant :

(a) à diriger le liquide de manière qu'il s'écoule à travers un canal d'écoulement de dimensions connues tout en exposant le liquide à un rayonnement électromagnétique;

(b) à mesurer l'atténuation momentanée du rayonnement électromagnétique produite par le liquide s'écoulant à travers le canal d'écoulement;

(c) à mesurer la transparence relative, à l'égard du rayonnement électromagnétique, du liquide s'écoulant à travers le canal d'écoulement, à des fins d'étalonnage;

(d) à déterminer, à partir de ces mesures, le volume momentané du liquide s'écoulant à travers le canal d'écoulement;

(e) à déterminer la vitesse momentanée du liquide s'écoulant à travers le canal d'écoulement; et

(f) à déterminer, à partir des étapes (d) et (e), le débit momentané du liquide s'écoulant à tra-

vers le canal d'écoulement.

2. Procédé suivant la revendication 1 caractérisé en ce que la transparence est mesurée en soumettant un volume connu du liquide au rayonnement électromagnétique et en mesurant l'atténuation de ce rayonnement.

3. Procédé suivant la revendication 2 caractérisé en ce que la transparence du liquide est mesurée en déterminant l'atténuation du rayonnement électromagnétique due au liquide tandis que le liquide s'écoule à travers un conduit de dimensions connues et remplit ce conduit.

4. Procédé suivant la revendication 3 caractérisé en ce que le conduit est un canal d'étalonnage séparé du canal d'écoulement.

5. Procédé suivant l'une quelconque des revendications 1 à 4 caractérisé en ce que la vitesse momentanée du liquide s'écoulant à travers le canal d'écoulement est déterminée, au cours de l'étape (e), en mesurant l'atténuation momentanée du rayonnement électromagnétique en deux points qui sont espacés d'une distance connue l'un de l'autre, le long du canal d'écoulement.

6. Procédé suivant l'une quelconque des revendications 1 à 5 caractérisé en ce qu'il comprend en outre l'étape consistant :

> (g) à mesurer des variations de l'atténuation du rayonnement électromagnétique en travers d'un trajet qui est en série avec le canal d'écoulement de manière qu'il soit soumis à la même température que celle du liquide se trouvant dans le canal d'écoulement, ce trajet ne contenant pas le liquide provenant du canal d'écoulement, et à commander, en réponse à cette mesure, le rayonnement électromagnétique auquel est exposé le liquide se trouvant dans le canal d'écoulement, afin de compenser les variations dc température et les effets du vieillissement.

7. Procédé suivant l'une quelconque des revendications 1 à 6 caractérisé en ce qu'au cours de l'étape (a), le liquide est dirigé de manière à s'écouler à travers une pluralité de canaux parallèles les uns aux autres; au cours de l'étape (b) l'atténuation momentanée du rayonnement électromagnétique est mesurée dans chaque canal de la pluralité de canaux d'écoulement; et au cours de l'étape (d) le volume momentané du liquide s'écoulant à travers tous les canaux d'écoulement est mesuré afin de déterminer le volume momentané du liquide s'écoulant à travers la totalité des canaux d'écoulement.

8. Procédé suivant la revendication 7 caractérisé en ce qu'au cours de l'étape (b), l'atténuation momentanée du rayonnement électromagnétique, mesurée dans au moins certains des canaux d'écoulement, est à des fréquences différentes de manière à fournir une information utilisable pour indiquer la composition du liquide s'écoulant à travers les canaux d'écoulement.

9. Procédé suivant l'une quelconque des revendications 1 à 8 caractérisé en ce que le rayonnement électromagnétique est un rayonnement infrarouge.

10. Procédé suivant l'une quelconque des revendications 1 à 8 caractérisé en ce que le rayonnement électromagnétique est un rayonnement haute fréquence.
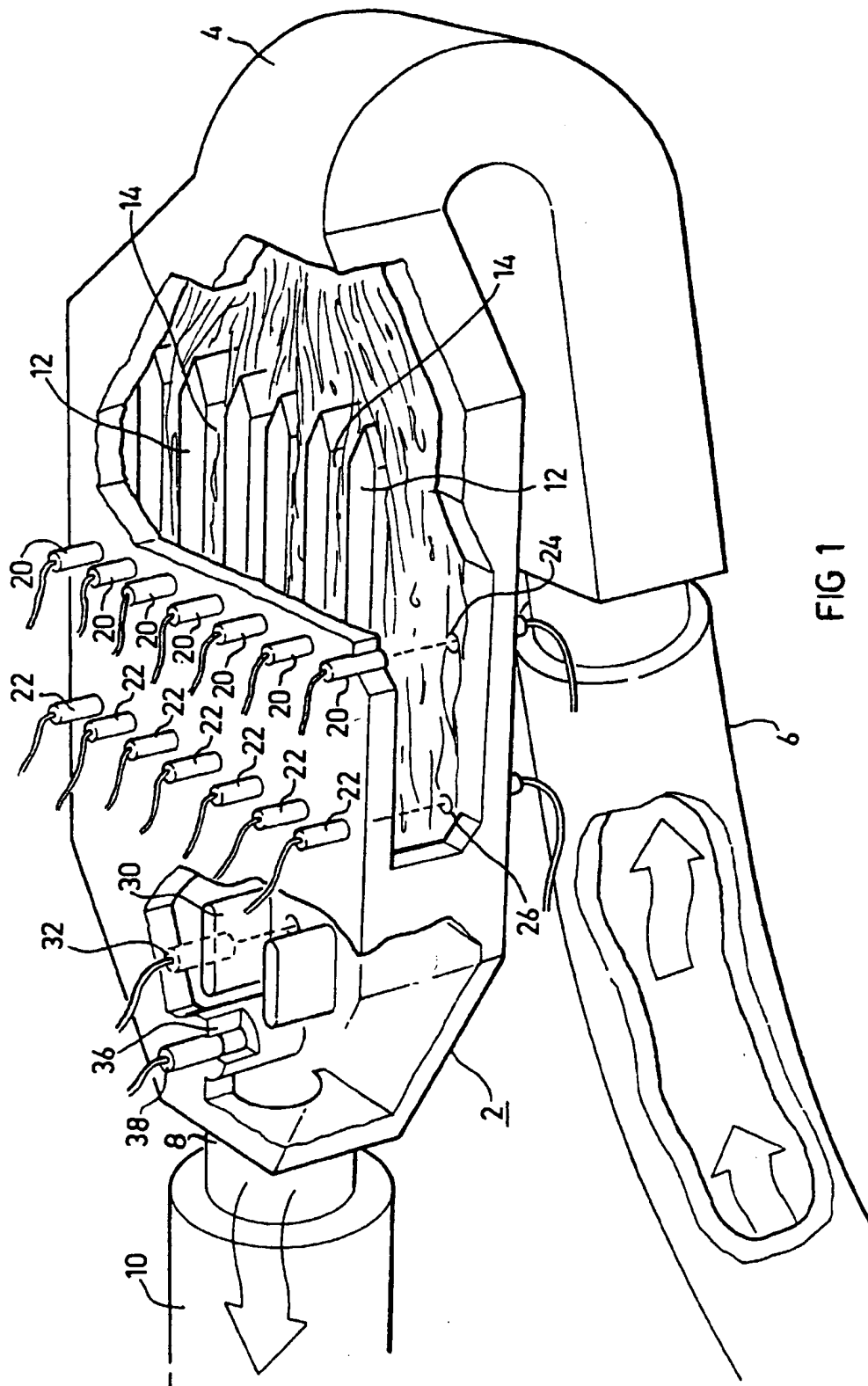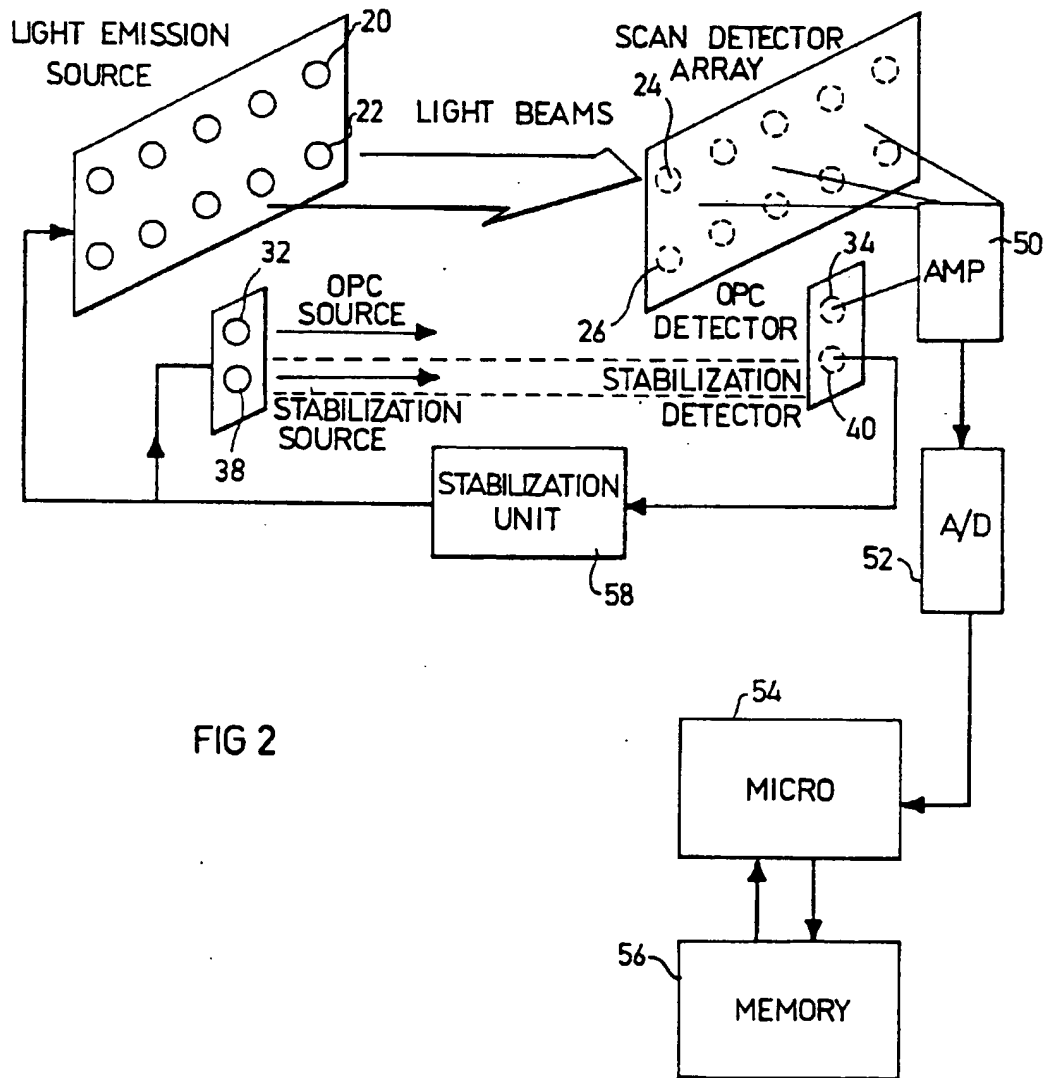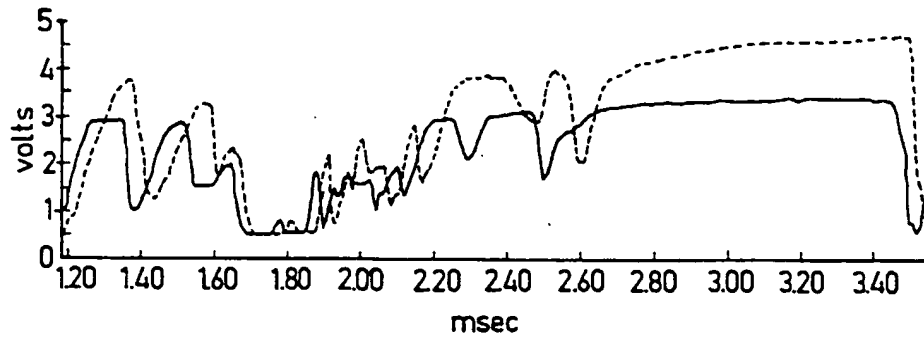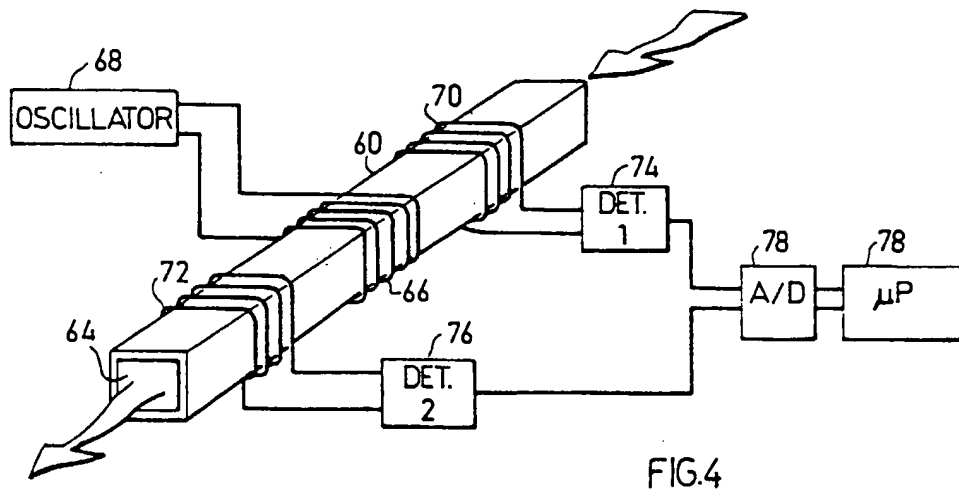
FIG 1

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FIG 2

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FIG 3

FIG.4

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